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CAN MULTI-PLANAR REFORMATTING RECOVER REPRODUCIBLE MORPHOLOGICAL ASSESSMENT OF FEMORAL CARTILAGE FROM MAL-ALIGNED CORONAL SCANS?

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Aim: Coronal MRI scans display superior precision of morphological measurements of femoral cartilage, but require a certain orientation of the scan (double bull's eye view). Since, in practice, not all scans can be acquired with ideal alignment, our objective was to assess whether multi-planar reformatting (MPR) of mal-aligned scans yielded reproducible morphological assessment of femoral cartilage of healthy and OA knees.
Methods: 9 healthy subjects (mean age (SD) 30.7 (6.4) y) and 4 with knee OA (70.5 (9) y) were imaged using an OrthOne™ 1T extremity MRI scanner. Four 3D coronal scans (SPGRE fat-sat, TR=59 ms, TE=10.9 ms, FA=37°, 0.31×0.62[interpolated to 0.31]×1.5 mm^3, 14:09 min.) were obtained within two visits over one week. During the first visit, two images were acquired having ideal bull's eye alignment with repositioning between scans to establish reference short-term precision errors. Imaging during the second visit constituted two images acquired with ±4.5° axial rotation from optimal alignment, resulting in a 3 slice difference, on average, between posterior ends of the femoral condyles. Mal-positioned data were corrected using the scanner's MPR software to generate optimally aligned images. One technician segmented the central medial (cMF) and lateral femoral (cLF) cartilage plates with proprietary software (Chondrometrics GmbH). Cartilage volume (VC), surface areas (tAB, AC) and mean thickness (ThCtAB) were determined. Average precision errors (RMS CV%) for healthy and OA subjects were obtained for aligned, mal-aligned and MPR data.
Results: Mal-aligned scans showed poorer precision in both plates (Table 1) other than for cMF.ThCtAB. MPR data showed better precision than mal-aligned data and, in some instances, exceeded the precision of the aligned images.

Table 1: Average RMS CV%

	cMF			cLF		
	aligned	mal-aligned	MPR	aligned	mal-aligned	MPR
tAB	2.0	3.4	1.4	1.1	3.6	1.3
AC	1.4	3.9	2.0	1.3	3.9	1.6
VC	3.1	4.5	3.9	4.4	7.0	4.3
ThCtAB	2.9	2.8	3.2	3.7	3.8	3.2

Systematic differences between aligned and MPR data were small and not statistically significant ($p<0.05$).

Conclusions: Our results show that mal-alignment decreases the precision of area and volume measurements and that MPR can recover or improve appropriate precision. Conversely, mal-alignment does not worsen the precision of thickness measurements and MPR does not appear to improve precision. In this study, a skilled operator diligently acquired the aligned images. MPR relaxes this constraint so that under typical operating conditions, measurements having comparable precision may be obtained. For 1T imaging, we recommend applying MPR to mal-aligned coronal scans. Because a small trend to systematic deviations between aligned and MPR data were observed, we recommend that in longitudinal studies, correction be applied to baseline and follow-up scans wherein mal-alignment may be encountered sporadically.

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HISTOLOGICAL CORRELATION OF MRI CATILAGE IMAGING IN THE KNEE JOINT BEFORE TOTAL REPLACEMENT

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Purpose: Regarding early osteoarthritic structural lesions there is still a lack of MRI cartilage assessment. Goal of the presenting study was to determine the diagnostic quality of 3 common sequences developed for cartilage detection by correlation to histological data in patients for total knee replacement.
Method and Materials: 8 Patients with severe osteoarthritis of the knee joint and indication for total knee replacement underwent in vivo 3T MRI with isotropic 3D-DESS (TR = 15.6 ms, TE = 4.5 ms, resolution 0.6×0.6×0.6 mm^3), 3D-MEDIC (TR = 31.0ms, TE = 17.0ms, resolution 0.5×0.5×0.5 mm^3) and 3D-Flash (TR = 12.2ms, TE = 5.1ms, resolution 0.5×0.5×0.5 mm^3) of the affected knee joint. The resected femoral condyle pieces were marked with 4 pins and imaged with the same MRI sequences but higher resolution (3D-DESS 0.5×0.5×0.5 mm^3 and 3D-FLASH and 3D-MEDIC both 0.4×0.4×0.4 mm^3) on the day of resection. Next the resected femoral condyles (Fig. 1) were fixed and semi thick slices of 0.4 mm were made with toluidin blue staining. The 226 histological slices of the 8 patients were staged according to the Mankin histopathological scale and registered by the pin location to the MRI data of the pieces. For the comparison to the preoperative MRI the angle correction of the cutting planes during operation was used.

Fig. 1

Fig. 2

Results: There were comparable results for grade 3 and 4 osteoarthritis for all three sequences with the histological data. For grade 2 lesions with loss of cartilage volume 3D-Flash and 3D-Medic were more comparable, for lesions without loss of cartilage thickness and loss of proteoglykans 3D-Dess (Fig. 2). For grade 1 lesion with superficial loss of staining 3D-Dess was also most sensitive, but with false positive results. For grade 1 lesions with loss of cartilage structure and increase of chondrocytes all sequences are highly false negative

Conclusion: In our study it was possible to register and correlate MRI cartilage detection histological findings. We found fare results for moderate and severe stages of osteoarthritis. It was possible to differentiate between loss of substance and loss of proteoglycans. However our results show still a lack of diagnostic efficiency in detection of early osteoarthritic changes in MRI.

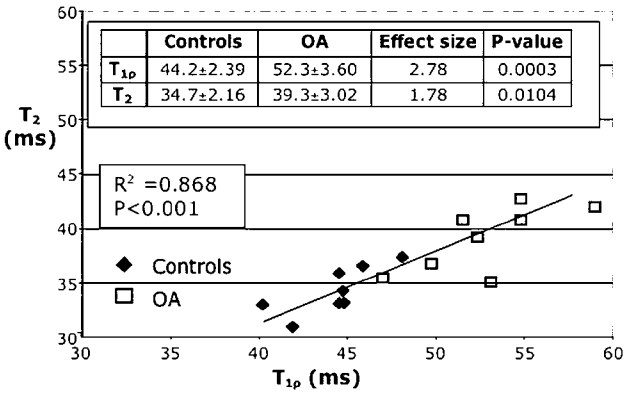

Fig. 1

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IN VIVO T1RHO AND T2 MAPPING IN CARTILAGE WITH KNEE OSTEOARTHRITIS AND THEIR CORRELATION WITH RADIOLOGICAL FINDINGS

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Aim of Study: Previously we have developed a robust and reproducible T1β mapping technique in knee cartilage. The goals of this study were to examine and compare the ability of T1β and T2 values to distinguish between patients with osteoarthritis (OA) and normal controls, and to investigate the relationship between T1β and clinical evaluation by radiographs and diagnostic MR images.

Methods: Eight healthy controls and eight OA patients with clinical OA symptoms and radiologic findings of cartilage degeneration were examined at a 3T GE MR scanner. The image protocol included T1β mapping sequence; T2 mapping sequence; 3D water excitation high-resolution SPGR images and fat-saturated T2-weighted FSE images. The radiographic findings were scored according to the KL scale. The MR images were analyzed regarding cartilage thinning (1: <50%; 2: >50%; 3: full), osteophytes, bone marrow edema, joint effusion, ligaments and meniscal tears, and other abnormalities. Five compartments were defined: the medial and lateral femoral condyle, the medial and lateral tibia and patella. Cartilage was segmented from SPGR images. The cartilage volume and average thickness were calculated for each compartment. T1β and T2 maps were aligned to the SPGR images. Mean and SD of T1β and T2 values were calculated. A rank test was used to compare average T1β and T2 values between controls and patients. The effect size was calculated for T1β and T2 as: effect size = Δ mean/SD where Δ mean is the mean difference between control and OA, and SD is the pooled SD of these two groups.

Results: The average T1β (in ms) was 48.3±1.98, 53.1±2.33, 53.3±1.70 for patients with KL=1, 2, 3 respectively, and 49.3±2.72, 53.3±1.23 and 56.8±2.90 for patients with cartilage thinning grade I, II, III respectively. The cartilage volume and average thickness were not significantly different between controls and OA patients for this population. Both the average T1β and T2 increased significantly from controls to OA patients, and the average T1β correlated with T2 significantly, shown in Fig. 1. The effect size was 2.78 and 1.78 for T1β and T2 values respectively.

Conclusions: T1β values were correlated with radiologic findings based on radiographs and diagnostic MR images. T1β and T2 values were significantly different between controls and OA patients while cartilage volume and thickness were not, suggesting that T1β and T2 are valuable in assessing OA, in particular in earlier stages. T1β has a higher effect size than T2 values, showing T1β may be a more sensitive indicator of cartilage degeneration than T2.

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DEPENDENCE OF 23NA QUADRUPOLAR COUPLING ON PROTEOGLYCAN DEPLETION

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Aim of Study: Determine the changes of ^{23}Na quadrupolar coupling constants (QCCs) as a function of cartilage degradation levels.

Methods: The high abundance of ^{23}Na in tissue offers promising prospect for 23Na-MRI as a powerful diagnostic method for cartilage pathologies. While both free and ordered (bound) sodium are prevalent throughout the body, monitoring the levels of the latter is of particular interest due to the strong correlation between changes in ordered sodium concentration and the early symptoms for most musculoskeltal disorders. The double-quantum filtered experiment, the Jeener-Broekaert sequences and experiments with shift reagents were previously used to selectively probe sodium signals in different environments. Recently, we described a new sequence based on frequency-swept pulses. These experiments show quadrupolar MIR contrast (QMRIC), in which pixel contrast depends on QCC values.

In this study we link the observed QCC values to proteoglycan depletion levels. Bovine cartilage samples (N=5) are treated with a trypsin/PBS (0.2 mg/ml) solution to produce proteoglycan-depleted samples. The QCCs are measured with a double-quantum filtered NMR sequence. ^{23}Na spectra are measured of the depletion medium to account for the amount of sodium that is set free. The cartilage measurements are performed with three different orientations (radial zone) with respect to the magnetic field, 0, 54.7, 90 degrees. The figure shows a representative set of experiments.